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Fast track article

Does network quality matter? A field study of mobile user satisfaction

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ABSTRACT

Mobile quality of experience and user satisfaction are growing research topics. However, the relationship between a user's satisfaction with network quality and the networks real performance in the field remains unexplored.

This paper is the first to study both network and non-network predictors of user satisfaction in the wild. We report findings from a large sample (2224 users over 12 months) combining both questionnaires and network measurements. We found that minimum download goodput and device type predict satisfaction with network availability. Whereas for network speed, only download factors predicted satisfaction. We observe that users integrate over many measurements and exhibit a known peak-end effect in their ratings. These results can inform modeling efforts in quality of experience and user satisfaction.

1. Introduction

The pervasiveness of mobile network connected devices suggests that understanding the effects of mobile network performance on user quality of experience (QoE) is an important area of research. QoE related results find many applications in, for example, mobile network management and optimization [1].

Thus, unsurprisingly, large volumes of research exploring the relationship between QoE and mobile network performance has been published [2]. Most of these studies have tended to focus on specific use cases such as QoE of mobile video [3] or specific mobile applications [4–7]. Relatively few studies have examined the related area of user satisfaction with mobile network concepts such as speed or availability [8]. Furthermore, studies that have examined this area have been customer satisfaction studies based only on user questionnaires without network data [8–10]. Additionally, related studies have also typically considered only a small set of network performance features such as download goodput, jitter, and latency and have considered non-network features (such as device type or device quality) out of scope (sometimes because non-network features were unavailable) [4–7]. Certain non-network features are important to include because they can effect the perception of network quality since, for example, users might incorrectly attribute device related application performance issues to the network.

Relatedly, mobile pervasiveness has also led to an increase in the number of users actively measuring the mobile network to ensure adequate network performance. Evidence can be seen in the popularization of a variety of mobile network measurement apps [11]. However the effect these user measurements and, as mentioned, real world network performance in general have on subjective user satisfaction remains unexplored.

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Therefore, in this article we study the network and non-network predictors of user satisfaction with network speed and availability in the context of user device based network measurements. Specifically, we combine user questionnaire responses and those questionnaire respondents empirical mobile network measurements from the device based network measurement platform Netradar [12]. This combination allows us to determine the significant predictors (aka features) of network satisfaction for those end users that themselves actively measure the network and observe the reported results.[1] Statistically, we utilize ordinal logistic regression modeling of the questionnaire responses to identify these significant predictors.

Furthermore, our use of the crowd-source based Netradar platform provides both a relatively large sample size (2224 Finland-based users) and real world data. For studying general network concepts recreating the diversity of real world network conditions in the lab is difficult. Thus implying that field studies with real world data should complement typical QoE and related lab studies. Additionally, for example, lab studies are often short in nature (minutes to hours) and thus might miss longer term (days to months) temporal phenomena such as user adaptation effects [13]. Though, importantly not all results will differ between lab and field trials and potential differences will depend on the specific use case as Schatz and Egger [5] demonstrated in a study combining lab and field trials.

In terms of results, we find that for network availability, minimum download goodput (over a user's measurements), number of frequently measured locations, network operator, and device type (smartphone or tablet) are significant predictors (in our ordinal logistic regression model). Whereas for network speed, we find that minimum, median, and most recent download goodput (over a user's measurements) are highly significant predictors. These network speed satisfaction predictors suggest that both an integration over measurements and a measurement peak-end effect influence the users evaluation. In addition, we find that predictors such as upload goodput, latency (RTT), and device quality, are not significant or only weakly significant given the other predictors. Finally, the overall fits of the result models are only basic thus other unaccounted for factors also likely play a part. Overall, our results have implications for mobile operators in terms of predicting user satisfaction especially in the context of users that measure and observe their own network performance.

We briefly describe the structure of the remainder of the article. Section 2 details the Netradar measurement platform and Section 3 details theoretical issues related to QoE and retrospective user evaluations. Section 4.1 introduces the questionnaire itself and Section 4.2 details the mapping of questionnaire respondents to measurement data and the filtering of respondents. Section 5 describes the measurement feature extraction process for each respondent. Section 6 gives a statistical overview of the resulting features and presents ordinal logistic models for each questionnaire question including significant features. Finally Section 7 discusses interpretation issues, Section 8 presents related work, and Section 9 gives conclusions.

2. Netradar measurement platform

This section briefly describes the mobile measurement platform Netradar.

Netradar is a popular client–server network measurement platform developed by researchers from Aalto University [12] and initially launched in February 2013. The platform consists of a suite of mobile applications (for different mobile platforms) and associated measurement servers distributed on several different continents. The application sends and receives bulk data to and from the measurement server to estimate network properties such as TCP goodput and round trip time (RTT). The application also simultaneously collects a variety of device information including location, mobile network operator, and platform (Android, iOS, or Windows Phone).

The Netradar client by default performs measurements on demand, in other words, whenever directed to measure by the user selecting the start button in the client user interface. However, the client can also be configured such that measurements are performed in the background (without the need for user intervention) at fixed or random intervals. In the context of the current study, we term measurements that are initiated by the user in the client user interface as *user-initiated measurements*.

During any single network measurement, any part of the Netradar client measurement process (RTT test, TCP test, etc.) might fail for a variety of reasons. For example, the mobile network might not be available (no signal) or the network might be highly congested. These failed measurements might be important indicators of poor network conditions and are not discarded. Even in the case where no network is available, the failed measurement information is stored locally and uploaded when a network connection is available. Thus we can track the total number of failed measurements and the reasons for the failures. In the context of the current study, we term measurements in which no part of the process has failed as *valid measurements* and measurements in which at least one part of the process has failed as *invalid measurements*.

In comparison to similar network measurement platforms Netradar supports all common features (upload/download/latency estimation, coverage maps, etc.) and thus is relatively comprehensive (refer to Table 2 in [11]). In technical terms, both Netradar and almost all other platforms utilize the bulk transfer capacity method as opposed to other methods such as trains of packet-pair [14]. Though Netradar uses TCP based upload and download tests whereas similar platforms use HTTP. However the effect of this difference should be minimal. Furthermore, Netradar supports eight different mobile platforms[2] compared to typical measurement platforms that support only two.

[1] Here we emphasize that we are studying users that observe the network measurement results including upload/download goodput and latency through mobile network measurements. We further discuss this issue in Section 7.

[2] Though as noted later, in this work we only consider three platforms due to time constraints with implementing the questionnaire in all platforms.

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